IMPROVEMENTS ON THE MODELING OF SURFACE TENSION-DRIVEN FLOW WITH THE CONTINUUM SURFACE FORCE METHOD

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The continuum surface force (CSF) method of Brackbill et al. [1] has been successfully and extensively employed over the last decade in the direct numerical simulation of multiphase flows with surface tension, in particular in volume of fluid (VOF) and front tracking methods. However, the CSF method has been shown to generate undesirable spurious currents near the interface, particularly when surface tension forces are dominant. Recent work has greatly reduced these spurious currents and decreased the deleterious effects with mesh refinement [2, 3]. The two main impediments, identified in [2, 3], that play an important role on the magnitude of the spurious current are: (1) the coupling of the surface tension force with the flow solver and (2) the accuracy of the curvature computation. In this study, we confirm these two impediments in the context of another flow algorithm with arbitrary density ratio. Regarding the first impediment, we present a consistent formulation within a VOF method using a pressure correction projection method to solve the incompressible Navier-Stokes equations. We show that a flow algorithm whose inherent design is motivated by legislating force balance will give exact (to round off) balance between surface tension forces and the pressure gradients that arise as a result. Regarding the curvature estimation, we explore several different formulations based on the VOF function, and delineate the pros and cons of each. We demonstrate that our formulation results in a reduction of the spurious currents for the standard test case of an equilibrium static drop. Two- and three-dimensional results of arbitrary density ratio (unity to infinity) free surface flows are used to illustrate these new developments.

References

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